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SOME POINTS  
IN THE  
PHYSIOLOGICAL AND MEDICAL ASPECT  
OF  
SEWAGE IRRIGATION.

A PAPER  
READ AT THE  
SOCIAL SCIENCE CONGRESS  
AT BRISTOL,

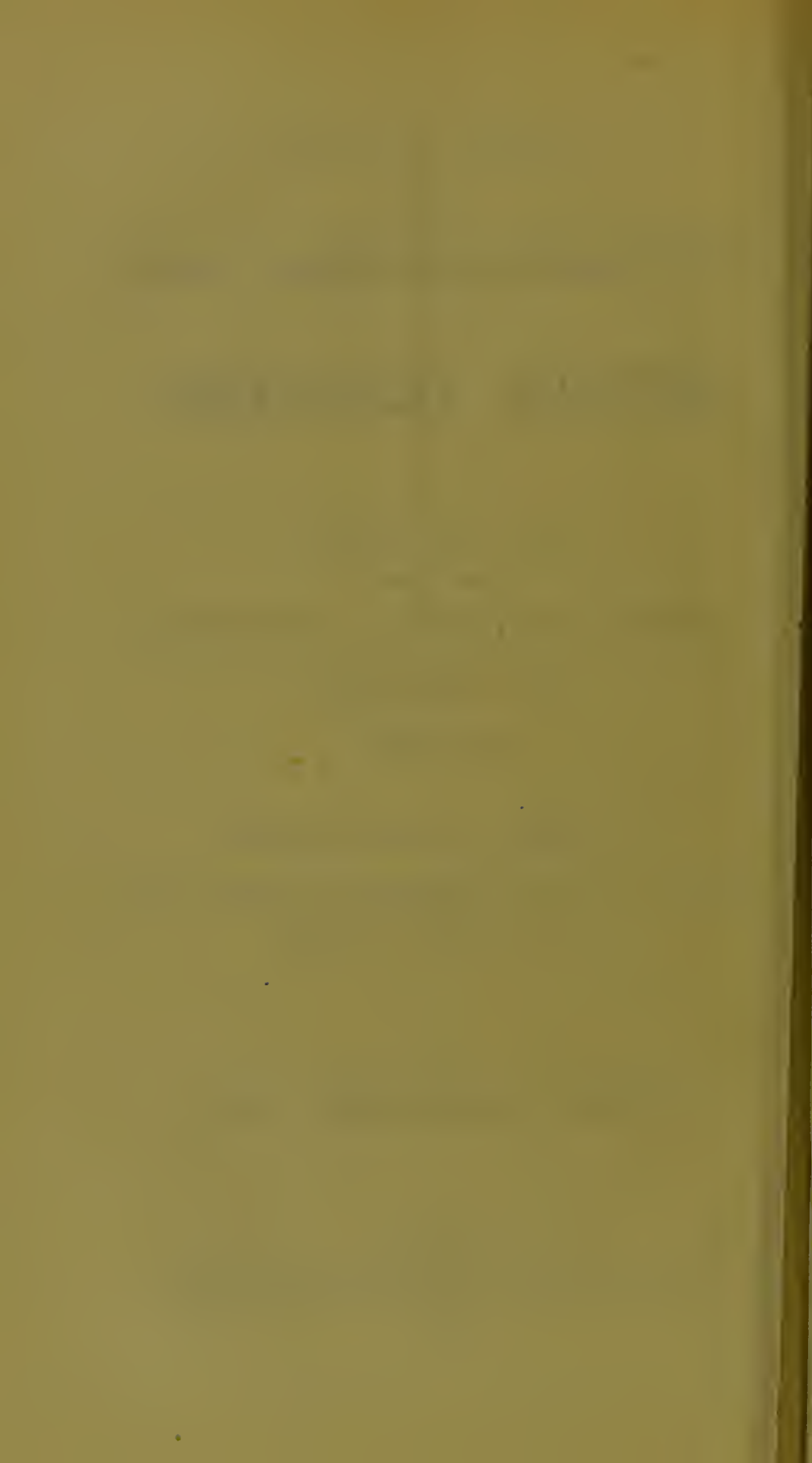
Oct. 2, 1869 ;

*TO WHICH IS ALSO APPENDED*  
A PAPER ON THE INFLUENCE OF SEWER GAS  
ON THE PUBLIC HEALTH.

BY  
ALFRED CARPENTER, M.D.

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CROYDON :  
PRINTED BY J. W. WARD, "ADVERTISER" OFFICE, THE BROADWAY.  
PUBLISHED BY F. WARREN, BOOKSELLER, HIGH STREET.

1869.



## P R E F A C E .

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THE accompanying Paper was read at the Social Science Congress at Bristol, October 2nd, 1869. The time at the disposal of a reader at a Congress is necessarily short, and some points are merely glanced at. I have thought it right, therefore, to add some Notes to the Paper, so as to explain more fully the references made therein, and thus help forward the proper elucidation of the important principle of Sewage Irrigation. I have wished to draw physiological inferences rather than give directions upon the practical management of a Sewage Farm. I do not intend to trench upon the domain of the Engineer or practical Surveyor, who must know more of the points within their jurisdiction than I can possibly tell them; and yet there are matters in connection with their work which theory may help to elucidate, and which fairly come within the province of the medical man to enquire into and make suggestions for future guidance, and so far I have presumed to go.

A. C.

*Croydon,*

*Dec. 8, 1869.*



## SEWAGE IRRIGATION.

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I SHALL preface my observations with a description of the term "sewage irrigation," as I understand it, so that the term I make use of may not be misunderstood.

I assume that the sewage is the ordinary sewage of an English town ; that it includes refuse proper to home manufactures only ; that it is applied to the land consistently and upon a regular plan ; that the land has been artistically laid out for the purpose of irrigation, on a proper level, and so arranged that the carriers do not foul ; that when the sewage is on the land it keeps moving and does not at all stagnate ; that it runs over the land rather than into it, and at most does not penetrate more than a few inches into the soil. (a) If there is no crop upon the land at the time of

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(a) There is at present much difference of opinion upon this point, some persons arguing that the sewage may penetrate as far as it possibly can ; others thinking that it must not go far into the soil—not, in fact, out of reach of the roots of the crop.

It is evident that those who support the latter idea are right. If the sewage goes beyond the reach of the roots it is lost ; if the interchange of elements does not take place, by which it is resolved into the salts, which indicate "previous sewage contamination," putrefaction results at some time or other, and gases may be given out which will be sources of evil, every time the earth is disturbed, raising marsh miasms, and being positively injurious to animal as well as to that vegetable life which is most useful to man. If the sewage penetrates beyond the reach of the rootlets of the crop, there will be an actual loss of useful material, and the financial result will not be so good as might be

application, then the sewage applied to the land shall not be in excess of its storing power; that it is fresh sewage, and not already undergoing putrefaction, and that the farm is managed by a skilful man.

I will also sum up the principal sanitary objections which have been made against sewage farms. They are:—

- (1.) That sewage irrigation destroys vegetation, and turns the ground into a pestilential swamp, from which unhealthy miasms must arise, causing fever, ague, dysentery, and general unhealthiness to those living near to the land so used, even affecting population miles away from it.
- (2.) That the wells in the neighbourhood would be contaminated with sewage elements by percolation, and thus also disease engendered.
- (3.) That the cattle fed upon such farms will be unhealthy, their flesh unwholesome, and their milk and butter unsafe for people to consume, and that the farms will be *foci*, from which disease will be spread to any cattle in the neighbourhood.

These I believe to be the main points of objection to the establishment of sewage farms. The principles I have briefly enumerated as necessary for their successful management will at once dispose of some of the objections made. A sewage farm must not be a swamp, it is no part of its plan to have anything stagnant upon it. A further definition of the

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obtained; for it is evident that, if the organic matter that is in the sewage is at once taken up by the vegetable kingdom, there will be the same quick returns which is the essence of healthy business, and the principle of transfer will be more effectual the more immediately it is carried out.

"Theory of sewage irrigation," will show that if the theory I am about to propound is true, none of the objections made against it can hold good.

The theory may be stated in a few words, viz., that the sewage of a town may be so applied to land that the rootlets of the growing crops shall at once seize upon the mischievous elements in the sewage; change their chemical forms, fix a portion of the elements in the plant, and render the rest comparatively harmless. This change will be effected before decomposition shall have advanced far enough for the dangerous elements to escape into the atmosphere, and so carry with them the germs of disease. That if the application to the land be properly managed, the whole of the materials supplied shall be at least rendered innocuous and the water perfectly freed from noxious organic matter. Is this definition of the theory correct? If it is so, the allegations made against sewage farms are groundless.

There are some points in the definition which require attention. The application of the sewage must not be in excess of the arresting power of the crop and the storing power of the land, or one of the conditions is not complied with. It happens that this arresting power is a point not quite easy to determine; it may be frequently overstepped, and a source of danger introduced which might at times seem to be uncontrollable. Nature, however, has placed two great safeguards against this chance of evil. The earth itself is a magazine in which a moderate excess of material may be stored with safety; and, secondly, should the excess pass beyond the storing power of the earth, then the nature of the crop, and the very act of growth of the plant, places a second safeguard in a production of ozone, which is discharged into the air above the crop, especially on those days when vegetation is most active and decomposition most rife, so that escaping elements of mischief, when moderate in



amount, are at once oxidised and rendered comparatively innocuous. Thus, I believe, it happens that only by a culpable negligence can mischief arise from sewage irrigation grounds.

It may at once be asked, How are these points proved? My answer is, that the work is seen in daily operation in the boudoir of almost every scientific lady in the kingdom, as well as in the drawing-room or the conservatory of every one studying the economy of nature. The action protecting an irrigation farm is precisely the action which keeps the aquarium healthy and free from noxious miasm. It is now well known that an aquarium may be kept for any length of time perfectly sweet and free from nuisance, but that if certain first principles be neglected, it becomes an intolerable pest. So it is with a sewage farm; like a railway or a steamship, it is dangerous if carelessly used, but that fact is not an argument against its employment. It is perfectly safe in the hands of those who understand it. (*b*)

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(*b*) It may be said that the very possibility of evil arising from sewage farms is a good reason for their non-introduction into a particular district: that as mischief may arise if they are improperly managed, it will be best for the landowner to resist their introduction at all. Such an argument is very short-sighted, and will assist, if carried into effect, in preventing that development of value which is sure to follow wherever a sewage farm is placed. If land which is worth, in an agricultural point of view, say 30s. per annum per acre, can be raised to £25 per annum per acre by sewage irrigation, it will assist in raising the value of every acre of land within easy distance of the farm; and I can scarcely think that landowners will be for long so blind to their own interests, as to object to their introduction.

The rage for railways has passed away; their value has been obtained. Now, any landowner would hail with great satisfaction the chance of a railway-station near to his land, whilst formerly it was looked upon as an intolerable nuisance, like to that which sewage farms are now supposed to be.



The first great point to be attended to is, to establish a proper vegetable growth ; the second is, to be careful that the *debris* of animal life shall not be in excess of the decomposing or fixing power of the vegetable. These are the most important points to be observed in commencing the cultivation of an aquarium.—These are the main points upon which the success of a sewage farm depends. If any one watches an aquarium in operation he will notice the bubbles of air clinging to the growing vegetation in the water. At times these rise to the surface, or are absorbed by the water before they reach the top. These bubbles of air are well known to consist of oxygen set free by the plant in its act of growth. I find that if this oxygen is collected it gives distinct traces of ozone ; it is therefore capable of oxidising very rapidly any noxious matter contained in the water, which would ordinarily interfere with animal life. The plant has decomposed the organic materials present in the water, has fixed the carbon, nitrogen and some of the hydrogen, and has given off a large portion of the oxygen in a form most fitted to complete any work which has not been perfected by nature's scavengers,

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The time will come when every town will want its sewage farm, and every landowner assist in promoting their formation. The only objection which can be fairly made to their introduction is that residential property of a superior character will be, to some extent, depreciated for residential purposes, in a manner similar to that with which the owner of a mansion would view the erection of a number of villas close to his borders, or of a manufactory of any kind close to his premises. His land becomes too valuable to retain for purposes of pleasure. Surely this is not an argument to be fairly used against the establishment of sewage farms. The other element of possible danger is no more to be entertained than that a steam-engine shall not be erected because it might blow up. The erection of a steam-engine may damage residential property ; but that ought not, and could not, prevent the erection.

and which, if left to decompose, would render the water unsafe for the continuance of animal life.

The late Mr. Ward was one of the first who pointed out and utilised in a popular way, the property of vegetation in giving out oxygen, as exemplified in the Wardian cases ; its principle was also verified by the late Mr. R. Warrington, who showed how perfectly the relations between the animal and the vegetable kingdoms were capable of being adjusted. The existence of ozone may have been also shown but not proved.

In corroboration of this point, I have found more distinct traces of ozone over a running stream which contains much vegetable growth than over streams without such so-called water weeds. I have tested sewage streams, and have found ozone quite absent in the air about them. It has been absent over streams with sewage and weeds, though present in the air generally. It has been present over streams where the weeds have purified the waters, or into which sewage has not been allowed to pour, and when also it has been shown by independent tests that ozone was absent in the air of a neighbouring station, whilst there have been distinct traces over a running stream which contained much active vegetable growth. At the same time, there was not a sign of it over an open sewer in which the sewage travelled as rapidly as in the river, where these experiments were made. Much difficulty has been experienced in carrying out these experiments from various causes which need not be detailed here.

We may now understand the providential spread of the American weed, the *Anacharis Alsinastrum*, (c) which C.

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(c) This extraordinary weed was introduced into England from Canada scarcely twenty years ago. It has spread throughout the land ; its beneficial effect as a sanitary agent

Kingsley calls the "magical weed," that has choked up our streams so wonderfully, has fattened on the mistakes of sanitarians, and whilst engaged in the office of purifying our water-courses, has assisted in preventing damage to our atmosphere, and foreshadowed the establishment of sewage farms.

We learn from the aquarium that, if the consequences of animal life overpower the vegetable growth, and also if the animal life does not remove the vegetable growth, both are destroyed, the whole of the ozonised oxygen being first taken away. If the vegetable growth is not removed it becomes more and more rank, and at length is financially worthless.

The same result will follow upon every sewage farm, upon which ignorance or carelessness allows imperfect work. If the levels are not correct, if the sewage is irregularly distributed, if it is in excess of the growing power of the crop, the proper plants are killed, rank weeds spring up, and the financial, as well as the sanitary state, is unsatisfactory, and miasms will arise to the injury of the vegetable as well as animal life.

Now, if it is safe for a large aquarium to be kept in a lady's boudoir, it is clear that a similar adjustment of animal and vegetable relation may be carried out on a larger scale out of doors, without the least risk to those near it. Indeed,

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was noticed by "Grindon in *British Botany*." It has saved many lives by purifying water-courses and water supplies which would otherwise have produced much evil and frequent death to those dependent upon such streams. Its development is very rapid in dirty streams, choking up water-courses and canals, and interfering much with navigation. The "Cam" is said to have been so much blocked up by it that a boat could scarcely get along, and thus it may have even helped Oxford to win the boat-race continuously. Thus often "do great events from little causes spring."

a sewage farm is safer than an aquarium, because the land has a property, which water at rest does not possess. It can hold a portion of the fertilising elements contained in sewage, and store them up against the time when the plant is ready to appropriate them to its own use. This property is possessed by some soils much more than others. It cannot, however, be stored *ad libitum*; it must not be stored in excess. It is found at present the safest in practice to use up the materials as fast as possible, and avoid a danger which storage may cause—viz., unequal distribution. The danger from this cause is greater in some soils than in others, because they are less retentive. Thus, argillaceous soils will retain the fertilising elements in larger quantities and for a longer period than sandy soils. It therefore follows that on a sandy soil the plant must be always at work, but on clay soils it may be stored up and used at convenience with greater safety. It is true that a process of filtration through a sandy soil tends to change the sewage elements into nitrites and nitrates, but this is not the direction in which a sewage farm should work to be profitable. It is not the deodorising, disinfecting, or re-arranging property of earth which is required, so much as the selecting power of the plant roots. We have no occasion to solve the very important question mooted by Pettenkofer, and mentioned by Dr. Rumsey, in his able address last year—viz., “that the germ of disease deodorised, but not disinfected, might be developed into active and dangerous energy.” (d)

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(d) Pettenkofer, a German physiologist of some status as an authority, has mooted this point, and put forth the idea that ordure mixed with earth may be deprived of its noxious smell, but that the germs of disease may still remain. Thus, he asserts that the excreta of cholera patients are not destroyed if they are mixed with earth, but may remain dormant ready to develop into activity whenever they are placed in circumstances favourable to their re-appearance. Supposing, therefore, that such earth containing ordure in

Such a contingency might happen with dried ordure, but the roots of the plant allow nothing to escape them, and no germs of disease will pass by without being made to stand and deliver up all that which can be appropriated to vegetable life, and which is everything likely to develop the germs of mischief, the very minuteness of the germs assisting to produce their own destruction.

As it is necessary for the success of sewage irrigation to have sufficient area for its complete use, it becomes an important point to determine how much land is required for a given population, so that all the fertilising elements may be taken out of the water, and the latter made perfectly safe to be returned to the nearest watercourse. This area must vary somewhat according to the density of the population, the character of the rainfall, and the still mooted question as to whether all the latter has to be provided for or not. The experience of some years has now shown that one acre of land will amply provide for the sewage of one hundred persons. In small towns and thinly populated districts the rainfall ought to be kept out of the sewers altogether, on the principle advocated by Mr. Menzies, but if the district is thickly peopled, 100 acres will be quite sufficient for both sewage and rainfall of an area occupied by 10,000 persons. This point has been fully proved in papers published by Mr.

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excess should become mixed with water, and that water should carry away the germs of disease into a supply of water used for potable purposes, the disease would be re-produced by those germs, though they had been previously mixed with earth. If this account is correct, it would shew that the earth closet plan is not free from a danger which cannot properly belong to sewage irrigation; for there is no doubt but that the roots of the plant will infallibly abstract every organic particle of animal origin existing in the water which passes by the vegetable, and not a single germ capable of re-producing disease can reach the effluent stream, if the fields are properly managed.



Baldwin Latham, and after ten years' experience we find the quantity fully equal to its work. (e) A reference to the report of the Royal Commission on Water Supply shows that the Wandle at Mitcham contrasts favourably with the Thames above Reading, although the former has received the effluent waters of the Croydon sewage farm, as well as actual sewage from several establishments between the place at which the water was taken, and the origin of the river in Croydon.

Because there is a chance of evil from the over-charged soil of a badly-managed sewage farm, it has been argued that they must, from the very necessity of things, be nuisances to houses in close proximity to them. The soil must not

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(e) The dilution to which the sewage is exposed will have some effect upon the result of irrigation. It must not be too concentrated, the quantity of water is of less moment than its density. The denser the sewage the more likely it is to do damage. Mixture, therefore, with rainfall in crowded populations will do no harm, especially if the farm is provided with sewage by gravitation, a large quantity of useful material will be brought down by such rainfall, the animal *debris* will be washed into the sewers from the streets, and much useful carbon with it from the roofs of the houses. If the sewage has to be pumped, there is an important question to be considered in the matter as to expense; but I consider that if it has not to be raised very high it will be advantageous to pump the whole, if the population is densely crowded; in thinly populated districts it cannot be doubted for a moment but that Mr. Menzies' plan is the proper one. All sewage farms will probably be all the better for 25 or 30 gallons per head per day of the population, rather than for a richer liquor; and if the water supply is defective, or should only reach on the average 8 or 10 gallons a day, it will be absolutely necessary for success to admit the rainfall, otherwise the sewers must be daily flushed to prevent that deposit which is destructive to sewage irrigation, and which is highly injurious to houses which are connected with the sewer so contaminated. A free supply of water and sewers free from deposit are conditions absolutely necessary for the perfect success of a sewage farm.

be over-charged, the farm must not be badly managed ; if it is it will fail and bring its own downfall, and its promoters be liable for damaging the neighbourhood. It has to be borne in mind that the flow of sewage must be fresh, that it reaches the soil a few hours at most after its discharge, and then the growing rootlets of the plant seem to take immediate possession of the changing elements. The appearance of the earth on a field of rye grass, under irrigation with sewage, is a perfect picturo of efficiency ; the ground is covered with an inextricable tangle of rootlets, the extremities of which seem to meet the sewage, and acting upon it, both mechanically as well as chemically, as a filter, take out everything required for their own use, and as the water passes from the field, especially after a second application, to another portion of land, the quantity of organic material in the water is absolutely less in quantity than when supplied to the inhabitants as potable water—[*vide* Report of Commissioners on Water Supply.] (f)

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(f) The report states (Note 202) that the attention of the Commissioners was called to the condition of the Wandle, and they instructed Mr. Pole to examine the effluent waters after they had passed from the land. They abstract from Mr. Pole's report the following item, the whole report itself being in the appendix. Mr. Pole says, "When I saw the system at work on May 11th, although the sewage was foul and dirty when it went on the land, the water running off was quite bright and clear, without any appearance of foul deposit in the channel. I noticed several fine trout in the river near the point of discharge, as well as in other places farther down. It is worthy of remark that the plan here adopted of allowing the sewage to travel slowly over the land, in constant agitation, among the blades and stalks of vegetation, appears to me peculiarly favourable for the oxidation of the impurities by the action of the atmosphere, which, I have no doubt, powerfully aids the purifying action by vegetable absorption."

The report then goes on to state some curious evidence with regard to the so-called "previous sewage contamination"



The opponents of sewage irrigation argue that whilst the crop is growing, portions of the sewage will become attached to the stalks of the grass above the reach of the absorbent ends of the roots, and that thus of necessity putrefaction must take place in a portion of the materials supplied; thus miasms may be produced dangerous to the health of the neighbourhood.

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which has been the great bugbear of the water companies during the last year or two. Dr. Frankland has shewn that this "previous sewage contamination" exists to a considerable extent in the water supplied to the inhabitants of the metropolis, and contends that such water is not fit to be supplied as a potable water, because the nitrates and nitrites contained therein must have had a sewage origin. From the Commissioners' report it will, however, be seen that the well water supplied by the Croydon Local Board and which is recognised as a magnificent potable water, contains  $\cdot 531$  parts in 100,000, or more than half a grain in 100,000, whilst in the water as sewage these nitrates and nitrites have all disappeared; but the ammonia has increased from  $\cdot 001$  to  $2\cdot 191$ , and the organic nitrogen from  $\cdot 007$  to  $1\cdot 156$ . After flowing off the land, the sewage contains  $34\cdot 4$  parts of solid residue, the ammonia being reduced to  $\cdot 002$  and the organic nitrogen to  $\cdot 037$ , the nitrates and nitrites having increased to  $\cdot 317$ . When it first passed on to the land it contained  $43\cdot 6$  parts of solid residue in 100,000, and a mile below the outfall the water had  $31\cdot$  or one part less than the Croydon well water.

At Mitcham, one mile lower down, the ammonia has all disappeared, and the nitrogen has again decreased to  $\cdot 007$ , but the nitrates and nitrites have increased to  $\cdot 403$ . This subject was discussed at a meeting of the Association of Medical Officer of Health in London some time since, and I asked Dr. Frankland to explain this anomaly. He did so by stating that he believed that the Croydon well was contaminated with sewage elements by percolation from the irrigated fields at Beddington. I pointed out the impossibility of this by reason of the following facts, viz., that the analysis of the well from which the town of Croydon is supplied, and which was made by Professor Way before the irrigated fields were

There seems foundation for this argument ; but the dense mass of rootlets I have mentioned, and through which it has to filter, soon render it unimportant in hot seasons when it is alone likely to occur. (g) In a dry season in

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laid out, nearly corresponds with Professor Frankland's own analysis. Secondly, that such percolation could not take place to any extent, because the gauge shews that, if allowance is made for evaporation, nearly as much water passes away from the fields at the outfall as passes on to them. Thirdly, that the level of the fields is below the level of the surface of the well from which the supply is taken ; and lastly, that the river Wandle itself runs the whole length of the distance between the well and the fields, and that if any supply was wanted for the well, it would reach it from that stream, and not from fields at a lower level many feet below the source of supply.

The Commissioners contrast the condition of the Wandle at Mitcham with the Thames above Reading, and shew that in the former stream the total solid residue is less than in the latter at Mitcham ; ammonia is absent, organic nitrogen is less in amount, and the nitrates and nitrites exist in the proportions of  $\cdot 403$  to  $\cdot 286$ , whilst at Mitcham carbon shews  $\cdot 099$ , but in the Thames it is  $\cdot 291$ . It must, in this case, be borne in mind that both at Beddington and at Carshalton much sewage does find its way into the Wandle which does not go over the irrigated land ; and that, therefore, whatever contamination does exist may be fairly ascribed to those places, and not to defective action on the farm. At the time of examination the whole of the sewage from the Female Orphan Asylum at Beddington, numbering 200 inmates, was discharged into the centre of the stream nearly two miles above the place at which the water was taken for examination by the Commissioners. We may reasonably assume, therefore, that this sewage contamination may account for the small amount of nitrates and nitrites which were so found.

(g) It is worthy of remark that the effect of putrefaction will be greatest at those times during which vegetation is most active, and that whatever promotes the one will promote the other. For instance, the action that takes place in vegetation after a frost is most marked ; the rise of sap in trees is very active indeed, and the action is very rapid in the plants which flourish on irrigated meadows at the break up of

the youngest grass, and when rain does not wash the plant, such a change may occur, but nature has fully guarded against the contingency by making the changes produced by the growing plant overtake and destroy the evil. The production of ozone takes place in the irrigated field as well as in the aquarium. The oxygen that is given off by the rapidly growing rye-grass upon the Beddington farm is ozonised. A double purpose is obtained by sewage irrigation—not only are the noxious elements contained in the sewage seized upon by the plant and fixed in the tissue of the plant, but should any of those elements advance beyond the point at which they are valuable, should they lose that value by putrefaction, and develop vibriones and their attendant miasms, then the development of ozone, which is continually taking place in the act of growth of the plant, prevents the flight of the miasm in a dangerous form, oxidises it on the spot, and renders it harmless. The conditions present, if a proper care has been used by the farmer, (*h*) prevent the possibility of that state in which all free oxygen has been removed, and which Pasteur has described as the period at which epidemic diseases arise.

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a frost. It is true that the product may not to the eye appear so great as in a fine summer's day; but it is nevertheless as certain that in a given quantity of material produced in spring as compared with a similar amount produced in a hot summer's day the amount of nitrogen and carbon which will be fixed will be *ceteris paribus* equal, whilst it is the excess of the water that will make up weight. I believe the concentrated absorption which takes place in February will as effectually purify the water as the more active growth of June and July.

(*h*) Pasteur has published the idea that it is in those states of decomposition in which all free oxygen has been removed that the germs of epidemic disease develop most rapidly, and run riot about the world. If this is so it follows that the development of free oxygen must stay the progress

If this theory is correct, and observations extending over a considerable period tend to corroborate it, there is good reason why rank vegetation should exist in malarious districts; for nature generally puts the bane and the antidote close together. I have found distinct traces of ozone in the Beddington fields, when there has been none in the town, and it has been noted how very rapidly metals rust upon sewage farms; this accounts for it. I have had the surface of the meadows tested at various times in the very hottest days of July, when no ozone has been detected in the town, but it has been present over the sewage grass, on those parts of the farm in which vegetation was most luxuriant. I have found it more abundant there than elsewhere when there has been very little wind, and it has scarcely ever been absent. This circumstance may explain the increase of appetite which is known to follow from a saunter among pine-woods, in which I have also found ozone freely developed, it may also assist in accounting for one peculiarity which is a well-established fact upon well-managed sewage farms. I have often asked the men employed upon the farm if their employment interferes with their health. I have on several occasions had from different men the same answer, viz. :—"Lord bless you, no, sir, but it do make us eat such a precious lot!" I was at first inclined to think that this answer was a little fun poked at my expense, but having had a similar reply from different men unknown to each other, and finding on further inquiry that the men

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of such epidemic disease. It is possible that instead of free oxygen, we should read oxygen in a state of change from one compound to another, or else oxygen in the ozonised form. If these are absent, then the germs of disease, whether as cholera or as typhoid fever, or any other epidemic form, may become rampant, and pestilences arise. Whatever, therefore, develops oxygen and fixes nitrogen and ammonia must tend to decrease the chance of epidemic disease.



really meant what they said, I believe that the oxidising property of the ozone there produced has something to do with the increase of appetite complained of, acting upon the men in a manner similar to that of the sea air upon the digestive organs of those who pay a visit to the sea-side.

Next to the sea, the surface of a well-managed sewage farm affords the largest supply of ozone, for here we have a continual motion of fluid, an active evaporation is always going on, the temperature of the ground is much nearer to a medium, being cooler in summer, warmer in winter, and there is the most active vegetable growth that can possibly be produced. The antozone, or peroxide of hydrogen, which probably accompanies the chemical changes, may likewise exercise a very important influence upon certain elements contained in decomposing sewage, tending still further to render them innocuous; especially the sulphur compounds when they are met with, and which are not always taken out by the plant, but upon this point I have no evidence.

Now comes an important question—How near may a sewage farm be placed to a given population without injury to the people? From the preceding observations it is possible for danger to arise, either by accident or design, for man is not infallible. It will be prudent, therefore, to have at least 100 yards between a row of houses and a sewage farm. Experience, as well as theory, has shown that this distance is amply sufficient. The visitor to Beddington will see a number of villas, which have been occupied for some years, with irrigated fields both in front and rear, whilst not a trace of enthetic disease has appeared in any of them, though I think the Beddington farm is capable of much improvement. At Norwood the population is much greater and much nearer to the fields, probably 400 persons living within 200 or 300 yards from the farm. Previously to its establishment in that district fever abounded; since then that disease has all but

disappeared, and the mortality of the district has steadily declined. The death-rate for Norwood population, about 5,000, for the last six years, according to Dr. Westall's mortality tables, is as follows, viz. :—

1863	...	18.76
1864	...	18.89
1865	...	18.17 Sewage farm established.
1866	...	15.34
1867	...	14.21
1868	...	12.07 (i)

From this table it will be seen that the establishment of the sewage farm in 1865 was immediately followed by a decrease in mortality, which would not have been the case if miasms had been promoted by their formation. Then, again, the Beddington farm of nearly 300 acres, is within 500 yards of a populous portion of our town, and within 900 yards of the centre of the place; it lies to the westward of the town, and yet I can safely say that a continuance of west wind is always accompanied by a diminished amount of ordinary sickness in the place, and our ordinary mortality is generally below 20‰. At Norwood, moreover, a public footpath passes right through the fields, which is frequented by hundreds of persons for recreation and amusement, especially on a Sunday. The persons so using the footpath have been frequently surprised when they have been told that their walks for pleasure have been taken through the sewage farm of the

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(i) I do not mean to assert that the low mortality in Norwood is due to the establishment of the sewage farm, neither do I expect that low rate to be maintained; but I contend that if miasms were produced by sewage farms, then the mortality would have increased after the establishment, and that preventible diseases would have more abounded than before the event. We find the contrary to be the fact.

Croydon Local Board of Health. The path is much more frequented than other footpaths in the neighbourhood, which would not be the case if the fields were the nuisance they are supposed to be.

The next point urged against sewage farms is that, from the very force of circumstances, the neighbouring wells must be contaminated.

This is a possible danger, but not a necessary one; if the ground is badly chosen, if the arrangements are not carefully made, if a fault exists in the geological formation of the ground, and the source of a well is in close proximity to it, and if that well is supplied by surface drainage much mischief might happen. This is not, however, a necessary result; it is the duty of those laying out the ground to mark the position of every well, study the character and the source of its supply, and so lay out the carriers upon the field that it shall not be possible for the dreaded contamination to arise.

It is quite certain that in a percolation of sewage through soil in which the strata are antagonistic to its progress, there will be a perfect re-arrangement of elements by which all noxious ingredients will be changed into harmless matters long before one hundred yards of earth have been traversed; we have also to bear a very important fact in mind, that sewage is expected to go over the ground, not into it. It is well known that earthy materials have the property of acting upon sewage, probably by a kind of catalysis in the act of filtration, so that if filtration is continued long enough, the materials which do get into the earth are altogether changed into nitrites or nitrates, or some other comparatively harmless form, which are formed out of contained organic elements. (j)

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(j) Dr. Frankland may or may not be right in the opinion he forms as to the origin of nitrates and nitrites, from a previous sewage contamination; but so long as the



Sewage water passed through twenty feet of earth of any kind, even sand, is so altered, and would be perfectly purified ; but experience shows that it will not so pass for any lengthened period, for a layer of clayey matter is developed within a short distance of the surface of the filter if the alumina in the filter is ever so little, and this soon renders the filter impervious to water. This action takes place upon irrigated lands, and would be perfect in its effect if it were not for the countless swarms of worms which develop beneath the soil, pierce the aluminous layer, and allow of moderate percolation, though much limited in the way I have mentioned. (*k*)

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water is not infested with organic germs—with living organisms or with ammonia compounds—the presence of minute quantities of nitrates and nitrites will not be in the least hurtful, but probably the contrary. The previous sewage contamination may have been thousands of years ago, and need not enter into consideration. If, however, the nitrates and nitrites should amount to more than a grain in 100,000 parts, it would be prudent to search for their origin, even if not accompanied with organic germs, so that immediate contamination might be detected as early as possible.

(*k*) There is a difference of opinion as to the propriety of under draining land which is to be used for sewage irrigation. *Prima facie* evidence would show that it is right to drain the land about to be so used by a deep system of drainage, so as to keep the land as dry as possible. It is, however, evident from the very nature of things that the land cannot be dry ; that if there is any outlet for sewage by sinking into the ground, it will soon worm its way through that outlet, and sewage, not pure water, will flow off. Experience has shewn that this is certain to arise. The rats, worms and leeches, which rapidly develop in the carriers, make holes through which the sewage will go without ever coming into contact with the vegetation or the earth, and the whole will fail, because if sewage gets into the ground beyond the upper roots of the crops, there will be at times putrefaction and its attendant evils. I should advise, therefore, that the surface of the land be so prepared that the sewage must run over it—not into it, or, at any rate, that it shall not run into it until it has

It is found, by actual measurement, on a well-regulated sewage farm, that the quantity of effluent water passing away at the outfall is equal to that which goes on to the land as sewage, allowance being made for the necessary evaporation from the surface of the field. This proves that even on the gravel at Beddington, no appreciable percolation takes place, if it is properly laid out. (l)

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passed over the surface ; that under-draining is not necessary, but liable to lead to failure ; and that the most important point is to get the water off the surface without penetrating more than sufficient to get into the small cuttings required to carry off the effluent waters. If the surface is regulated aright, and no deep cuttings are made, there will be much less danger of evil and a very great expense saved. The farmer would smile if he was advised to let his guano get deep into the ground, and not trouble himself about top dressings, and the gardener likes his manure on the top of the soil, because he finds from experience that his crops are better if the manure is kept on the surface. It will be evident, therefore, that an argillaceous soil will suit the purpose better than a sandy soil ; though it will be always best, if possible, to have a farm consisting of both kinds of soil—the one for Italian rye-grass ; the other for the consumption of the products and the production of other crops which are requisite to make a sewage farm most profitable, and render the farmer independent of outside customers for his grass. The disgraceful state in which portions of our farm at Beddington exist must not by any possibility be allowed to arise. Cattle ought not to be kept on the farm where the fields are irrigated, as their feet must produce a swampy state incompatible with proper sewage farming.

(l) Mr. Latham has designed some pipes for the conveyance of sewage on to irrigated land which are admirably adapted for the purpose they are intended to serve. They are cylinders made of tile clay, with a series of holes upon one side for the sewage to flow from them by welling up on to the land. They act as carriers, and are just sunk into the ground so as to be even with the surface of the field, and yet to occupy very little of that surface, and do not take away therefore from the area under cultivation. It will be observed that the vegetation is very luxuriant on each side of the

The third set of serious charges made against sewage farms is, that the cattle upon them are generally unhealthy, that they are remarkably prone to various diseases, "that the process tends to produce disease," and that the products of such cattle, the meat, the milk, and the butter, are unsafe for people to consume.

Those connected with sewage farms do not find that these are true assertions. The personal appearance of the cows at Beddington is admirable. Their coats are sleek and glossy, their flesh firm, and their general appearance such as must delight the sight of a good farmer. These facts are well known to those cultivating such farms. The statement, therefore, published the other day in the *Times*, and repeated at a public dinner, consisting mainly of farmers, by a member of Parliament for a part of the county of Surrey, stating that the foot and mouth disease first made its appearance among the cattle pastured upon the Croydon sewage farm—that the cattle were dying by scores by reason of the outbreak, took agriculturists by surprise. It was stated that this was the second outbreak of disease among the cattle pastured upon this farm. These statements, made upon such authority, will be copied into every paper, and used as an argument against sewage farms, wherever it is proposed to place one; for the *Times*, for some reason or other, did not insert Mr. Marriage's correction of the error, and writers have already assumed that it is correct. I will now submit the actual facts. First, as regards the rinderpest, which Mr. Smee accuses the sewage farm of promoting. It is a positive fact, which can be easily

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cylinder, and grows there most rapidly after each cutting; that the position of the carrier is at once seen on a field by the more luxuriant growth of grass. These cylinders prevent any ill-consequence from the carriers becoming foul, they cleanse themselves, and when examined after a cutting, are seen to be perfectly free from any noxious matter whatever.

shown by the record of the Inspector appointed by the Croydon Local Board, that, although Croydon and Norwood were in the very centre of a district greatly affected by the disease, the mortality among the cows which were fed upon the sewage grass in Croydon was very much less than in other parts in and near the metropolis, which had not the benefit of such food. At Norwood, where the whole of the grass grown upon the sewage farm is sold to the cow-keepers of the neighbourhood, not a single case of rinderpest was reported in the Croydon part of the district. Some few steer stock were slaughtered upon Mr. Marriage's farm, because there was a possible chance that they might have been infected from a certain cause ; it was done as a precautionary measure, and nearly at the end of the epidemic. Until it was nearly over, not a sign of it was seen at Beddington, and it never made its appearance among the cows on that land at all. On this last occasion, the foot and mouth disease, which, by-the-bye, is not murrain, made its appearance at the outports as well as in South London, in Kent, and on the Surrey Hills, before it reached Mr. Marriage's farm, and then it first appeared among the steer stock and not among the cows. Mr. Marriage informs me that the first cases appeared in the beginning of August, about the 4th,\* after an announcement had appeared in the daily journals of the prevalence of the disease elsewhere. He says, in a letter to me, that the cases have been quite mild, not one fatal, not one slaughtered ; that the whole are now (September 10) perfectly well, and that they did not require any medical treatment. Mr. Marriage states that in his belief the mildness of the disease was due to the rich, fresh, succulent sewage grass with which they were fed—that

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\* Mr. Mitchell, sanitary inspector of the parish of Croydon, reported that forty-seven head of cattle on Pollard's Hill (high ground) had the foot and mouth disease, on July 20, 1869 ; he reported that at Streatham police-station, on July 22.

his cases suffered much less than those not so fed. I think these facts are conclusive proofs of the unfounded nature of these charges against sewage farms.

It is acknowledged that cattle eat rye-grass most voraciously. The cow-keepers in the neighbourhood of sewage farms soon find this out, and also, what is to them a still more important fact, viz., that it produces a much more abundant supply of rich milk than any other similar kind of food. Now, a crowded population produces that sewage which brings the necessity for sewage farms. It is also in a corresponding ratio a market for milk; the poor of our cities at the present time do not get milk at all, and the so-called butter is scarcely produced by cows. The price of these articles in their pure state removes them altogether from the home of the poor man. It may be very pertinently asked if a more sanitary act could be performed under existing circumstances than sending into the city in return for the sewage, those things which are really necessary articles of diet, but which cannot now be obtained. This return a sewage farm can give, and also assist in reducing the famine price which meat has nearly reached, mainly in consequence of the decrease of green food for cattle.

The character of the milk and butter obtained from cattle is considered a good proof of the kind of food consumed by them. I will upon this point quote the authority of Mr. R. W. Fuller, an agriculturist and land agent of some standing in the south of London. He states (*Croydon Chronicle*, March 2nd, 1869), "That if there is one thing more than another by which improper food given to cows might be detected, it was in the flavour given to butter. This was a test which never failed. Ever since Mr. Marriage had had the Beddington farm he (Mr. Fuller) had purchased the grass grown upon those fields. His cows and horses were fed with the grass, and they were never



so well or so healthy as when fed with the grass. The milk was excellent and in superior quantity, and with regard to the butter he could most positively assert that its taste and odour were perfect. His cows stood in their sheds with nothing to eat but the grass and a little artificial food, and no animals could look better or more healthy than they did."

Mr. Fuller stated at the same time that the butter will quickly show if the animal has had a change of food ; turnips, mangel-wurzel, and oil-cake, each rapidly making itself manifest by the odour and change of colour in the butter, but that rye-grass gives no odour, no colour, but that which properly belongs to the article.

It has been broadly asserted that the milk from sewage farms is unwholesome, and does much injury to children consuming it. Now if this were so I should have proof of it very soon ; a large portion of the milk produced at Beddington is consumed by the families of London citizens, living in or near Croydon. The mortality amongst those children is remarkably small, whilst it is comparatively large among the poor, who scarcely get any milk at all ; and my own observations go far to prove that the children who get plenty of milk are the healthiest part of the population, and the least troubled with diarrhœa and gastric maladies in general. (*m*)

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(*m*) It has been said that the aphthous mouth now often seen among children is due to the milk of cows which have been affected with foot and mouth disease.

I have carefully enquired into this point. I have met very frequently with this aphthous state of mouth ; but the majority of the cases have been observed among persons who are exposed to the influence of sewer gas and cesspool emanations rather than to such milk. The first ten cases that I was called upon to treat this autumn occurred in children of

Lastly, it will not be out of place to say a few words upon the temperature at which sewage is applied to land. A visit to the meadows during the continuance of frost or snow is instructive. Vegetation still goes on; the frost must be severe and long-continued to put a stop to the process of sewage irrigation, and even then the stoppage is caused as much by the failure of supply, as from the cold on the ground.

If the water is kept moving over the field the surface does not easily freeze, and the roots of the plants are much better protected when enveloped in water than when in the frozen ground. Mr. B. Latham has published some important facts bearing upon this point. He shows that when the greatest degree of temperature is required the sewage possesses it. That it increases with the duration of the frost, probably arising from the fact that much less cold water is used in cold weather than at other times. He points out that the temperature varies according to the source of the water supply.

Thus the water of the town of Croydon being obtained

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parents who lived in detached houses away from the town, and who were not fed with milk from diseased cows most certainly, but with milk from private sources, and who were exposed to cesspool influences.

The majority of children in Croydon, having milk from cow-keepers, have probably had milk more or less infected during some portion of the autumn. Yet, cases of *aththæ* have been quite unfrequent among them, compared with the small minority of persons not so supplied, whilst it has been more frequent among those having no milk at all than among those abundantly supplied. These facts quite upset the theory of those who contend that the disease is dependent upon such milk. The use of milk from diseased animals is not to be encouraged under any circumstances; but it is best to saddle the right horse, and I think *aphthæ* is more often due to want of milk, and the presence of decomposing or fermenting animal matter of another kind, than to milk.



from a deep well, produces sewage, having a higher and more uniform temperature than that produced at South Norwood, where the water supply is from the Lambeth Company. At Norwood the sewage had an average temperature of 41 degrees, whilst the air ranged between 33 degrees and 10 degrees; but that at Croydon, the air ranging between 31 degrees and 24 degrees, the temperature of the sewage was 51 degrees. This proves that the sewage raises the temperature of the land in cold weather, whilst the converse is the case in great heat; it is cooler in hot summers than the surrounding land.

Hence it must happen that an extended area under irrigation must have some influence in moderating the temperature of the neighbourhood, making it approach nearer to a general mean. These facts also quite dispose of the assertion that frost and snow must necessarily arrest the action of irrigation, and give rise to much mischief on the break up of the frost. If the frost is severe or of long continuance it must be felt, but not on the irrigated land to an injurious extent, for very little sewage will get there at all; vegetation will not be required to purify it, but as it breaks up the roots of the rye-grass are found to come immediately into action, and the warm weather, which usually follows a frost continuous enough to freeze the surface, is accompanied by a most rapid development of vegetation upon the fields, and, as a consequence, a purification of the sewage. So that, whether in the depths of winter or the intense heat of the hottest summer, they present an evergreen appearance most refreshing, and if properly managed are benefits instead of injuries to the neighbourhood.

# INFLUENCE OF SEWER GAS ON THE PUBLIC HEALTH, AND THE THEORY OF VENTILATION AS REQUIRED IN SEWERS.

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By ALFRED CARPENTER, Esq. M.D.,

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*Read at a Meeting of the Health Department,  
Monday, June 7th, 1869.*

THE influence of sewer gas upon the public health is one of those matters which, though suspected for a long time by the close observers of nature, and for some years plainly asserted by physicians, is now only becoming an established fact in the public mind.

As a consequence of the impression produced by this fact, the laws of nature are frequently ignored by those whose duty it is to take measures for the prevention of the influence; thus the knowledge gained is rendered nugatory, and opprobrium is often thrown upon things which do not deserve it.

It was not until the general introduction of water-closets and the pipe sewer system, that the injury produced by sewer gas was sufficiently isolated to be positively identified. Previous to that time its effects were occasional only, and always combined with other causes, which prevented its identification as a positive factor in the production of disease. They were shown in promoting the spread of epidemics by emanations from stagnant ditches, and the elongated cesspools formerly

called sewers, as also by miasms from the seething filth surrounding populous districts. These effects became more manifest on those days, and at those periods of time, when the air was stagnant, and the telluric influences (whether magnetic or otherwise) were those of a negative character, and when putrefactive changes were more than usually promoted.

Cesspools and privies became so offensive to the nose, that the invention of the water-closet was hailed as a boon by the luxurious and the lovers of comfort, and ultimately it became a necessity in every well-regulated establishment. Cesspools were denounced; the smell from the open privy was an abomination which could not be allowed. The result of this change in the habits of the people has been a clever contrivance, by which the gases developed by commencing decomposition in the cesspool, which used to escape into the open air, and not do much damage, except at uncertain intervals, are quietly and continuously conveyed into the houses of the people in a form more dangerous than those decided stinks which arose from the effects of more advanced decomposition in the open air. This result of the introduction of water-closets within the walls of our homes naturally casts a reflection upon the w.c. which is not altogether deserved, and which need not necessarily be borne. It has arisen from a neglect of a natural law—viz., not providing for exits as well as entrances; sewers not being, like soda water or champagne bottles, sufficiently impermeable to allow of being charged with the gas under pressure.

It was not to be expected that civil engineers would know anything about the dangers of sewer gas until its power had been pointed out by medical men and others who had become cognisant of its effects, and from the causes previously mentioned there was no positive evidence before the scientific world. In the early sanitary works, therefore, which were carried out under the supervision and with the approval of

the general Board of Health, and under the authority of the Public Health Act of 1848, the consequences of sewer gas not being foreseen, were not guarded against; no provisions were made to prevent its ascent into the house, or for exit into the open air before it could reach the inside of the dwelling.\* The rapid spread of luxurious habits among the people, the introduction of low fire-places and register stoves, and the methods adopted to exclude draughts by having exceedingly close-fitting windows and doors, prevented its easy exit, and its baneful influence became manifest, often without the real cause being at that time at all suspected. From these circumstances it often happens that the easiest way for air to enter the house is by the sewer. Thus it was that many towns, having availed themselves of the provisions of the Public Health Act, and the services of the engineers approved by the first Board of Health, found, to their cost, that after an arduous battle with the preservers of filth and the powerful anti-rate party of the period, at the very time when they began to crow over their victory, they had a still more arduous battle to wage, because fever would develope

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\* Mr. Edwin Chadwick repudiates this statement, and refers me to his own report made in 1842, on the sanitary condition of the labouring population of Great Britain, for evidence of his own denunciation of the effects of sewer gas. From this report I gather that the consequences were certainly foreseen by Mr. Chadwick; but whilst he believed that the pipe sewers were self-cleansing, he did not deem it necessary to insist upon safety valves against the chance of the consequences of deposit, and authorities who had to carry out the works were quite ignorant of such necessity. Deposit sewers was the rule, and self-cleansing sewers the exception. If Mr. Chadwick had been dictator, such a condition would not have arisen, for he would have had well laid sewer pipes everywhere. I only therefore state a fact as far as the effect of the works is concerned, and bear testimony to the searching enquiry made by Mr. Chadwick in his report, which I had not consulted when I read the paper.

itself where it seemed that it had no business to come. Thus the town of Croydon suffered in the moment of victory, even before its first works were completed. The local authority, at its wit's end to discover the cause of this untoward state of things, searched everywhere for advice, and had a multitude of counsellors, without at that time being able to find out the cause of the only partial success of the plan they had adopted.

True, it was generally suspected, and several eminent men mentioned, among the faults of the system, that proper ventilation was not provided, and suggested various alterations. Thus Mr. Simon, who was requested by the local Board to advise them upon the matter, says—

“If you have given your constituents rapid inodorous sewerage, with pure and constant water supply, instead of cesspools with their soakage; if you have made six feet difference in the water level of your low-lying district; if you have removed such ponds and ditches of filth as existed within your town; these are inestimable contributions to the public health, which must bear their fruits so soon as you remove those interfering causes which have hitherto masked the result.”

Well, the interfering causes, as pointed out by Mr. Simon, and other eminent men, were removed, as well as the knowledge of the day would permit; certainly with advantage, and with a decrease of the clearly introduced disease, which disease, as Mr. Simon remarked—

“Was not in poor houses, not in ill-drained houses, not in dirty houses, not in low-lying damp houses, but in houses where least of all one would expect any ordinary cause of fever to be in operation.”

Nevertheless fever would recur; fever always the same in type, “the enteric or typhoid” form, with rose-coloured spots, often with abdominal complications, and always in those houses nearest to the top of the sewer (perhaps I should say generally) and farthest from the outfall. At first it was the centre of the town which suffered, but as the drainage area extended the outskirts became more liable,



whilst the centre, and houses on the first-formed sewers, escaped. Attention was continually drawn to individual cases; they were often associated with smells, suggesting that foul air found its way into the house by some opening in communication with the sewer, which was not protected by an efficient trap. Orders were given to trap the opening, and it was supposed that the mischief was remedied; so it seemed to be, as far as that house was concerned; but the disease often made its appearance, soon afterwards, in the next house, or in near neighbourhood, upon the same line of sewer, or even in the same house again, as soon as something happened by which the trap was put out of order and rendered inoperative; at times trapping did not stay the mischief, because ineffective, and it was thought then, that the smell had nothing to do with the disease.

Many facts have been brought to my observation as to the power of sewer gas, or some matter conveyed by sewer gas, to produce disease. As a factor in the production of typhoid fever its power is now well known; many other disorders of the system have been directly traced to its influence—thus diarrhoea; dyspepsia in all its forms; palpitation of the heart; various forms of asthma—indeed it may help to explain some of the vagaries of this curious disease; convulsions, especially in teething infants; headaches, both persistent and intermittent. The evils which sometimes attend or follow upon the puerperal state, as milk fever, abscesses in the breast, and phlegmasia dolens or white leg, are frequently caused by it. I believe that these latter cases have been so associated, from observing their frequent occurrence in new houses before the plan now adopted in our district was carried out, compared with their infrequency since the adoption of that plan.

It seems to me that, in a great number of instances, the necessity for a change of air, after a serious illness, has arisen rather from the difficulty of escaping from the effects

of sewer gas than from any real want of power on the part of the body to overcome the weakness induced by the attack. Some constitutions are much more liable to suffer from its effects than others; it evidently in some cases has a very curious effect upon the nervous system. It is no unusual thing for a person to faint away without any assignable cause, but which may really be sewer miasm. I have notes of a case in which a lady could not go into certain houses because she always fainted there, and those houses were undoubtedly imperfect in their sewer arrangements. If it was not for the introduction of such gas into our houses when no ozone is present to alter its form, or to be in excess of the quantity necessary to destroy the miasm present in the air, the absolute requirement of change of air would be comparatively infrequent.

This idea may seem far-fetched, because in many cases of illness smells have not been perceived, or even scarcely suspected. But if there is an untrapped opening into an imperfectly ventilated sewer, or if it is trapped in the ordinary way, and is in connection with the ordinary London sewer, which, as a rule, is very imperfectly ventilated, then it is evident that such a gas can get into the house. We know that it is not the solid stink that is most dangerous to the public health, but the insidious miasms often unperceived, and, until its effects are produced, unsuspected.

If we see those effects upon the human body, effects which have been proved to have been caused by such miasm elsewhere, and we know that it is possible for such miasms to be thus present, surely it is not necessary to complete the chain and prove the truth of the problem, by smelling the smell upon which the disease depends, a smell which is easily overpowered by the other scents always existing in ordinary households, and which themselves assist in de-ozoneing the atmosphere. Ozone, I contend, is the agent which will alone remove the injurious consequences of sewer gas. It is not an



absolute proof that no evil arises from an opening because at that opening the smell is not perceived. I have traced smells from places which, at the moment of exit, have been unperceived, but soon afterwards have been most decided stinks, the oxidizing influence of the air producing perfumes of various kinds, sometimes agreeable, at others, and more often, the contrary. This effect has been very marked at a certain oil-cloth works near our town. The emanations from that place are most unmistakeable, yet on a cold frosty evening the smell close to the place has not been noticeable, whilst half a mile away from it the odour has been most offensive.

This is neither the time nor place in which to detail cases which have come under my own observation, but I may be allowed to adduce the fact that, previously to the introduction of the plan now adopted in my own town, occasional outbreaks of fever used to puzzle, notwithstanding the insertion of ventilating pipes, and the occasional use of the rain-water pipes for the same purpose.

On inquiry, and continual research, I found that these cases always occurred after dry weather, and shortly after a succeeding heavy rainfall. That the cases occurred near to the dead ends of long lines of pipe sewers, that an extension of those sewers removed the fever higher up, and relieved the houses formerly affected. That the fatal cases most often occurred in houses at the very end of a sewer, and farthest from the outfall. That the inmates of those houses had been probably breathing the sewer gas for a long period in a less concentrated form, before its final onslaught, and before the system became sufficiently charged to enable the change to arise in the blood, the total of which is called "typhoid fever." If the total is not reached, the disturbance may take on one of the disorders I have already mentioned, or even merely produce a want of power. Chemists tell us what small amounts of material help to entirely change the form of bodies and alter their constituent particles; who shall say

how much the ordinary chemical actions which take place in the nutrition or purification of the body, may be interfered with by such gases ; it seems certain that one effect is the decrease of red blood corpuscles, but how brought about one is only able to conjecture.

When a stink is perceived at a particular spot, or in a particular house, orders are generally given to stop the place of issue, by trapping the offending opening, with the beneficial result of removing the smell, and staying the progress of disease in that particular house or place ; but no means are taken to prevent its influence being felt elsewhere. The mischief is simply transferred in a selfish kind of way, and the public suffer for it. I have had much experience of this kind of thing in our district, and soon saw that trapping was not a proper remedy, unless it was accompanied by the provision of another exit. This has been clearly made out upon lines of ordinary sewers, but it has been even more manifest in detached sewers ; that is, sewers not connected with any general system. The effects of trapping were very marked last year at the Warehousemen and Clerks' Schools, on Russell Hill. These schools accommodate some 160 children, they were opened nearly three years ago, and at first the children enjoyed unusually good health, but in the autumn of 1867 typhoid fever made its appearance. It appears that a smell, slight at first, but afterwards very intense, had been perceived in the laundry. The place of exit was trapped, and the smell prevented at that place, but as no other place of exit was provided for the sewage gas until it reached the interior of the building, it was conveyed from the cesspool by the pipe sewers into the lower part of the building, and then into the class-rooms. Now, in cold damp weather they do not so freely ventilate such buildings as much as might be. The rooms being warmed by hot water pipes have no open chimneys to produce draughts. The hot summer was followed by heavy rains, fires had not been commenced, and the rooms were

not chilled by having the windows opened. The children would get up in the morning and go down to work in their class-rooms before breakfast, and inhale the sewer gas, when they were least able to resist its influence, and when it was most concentrated, viz., on cold damp mornings after heavy and warm rains had stirred up the deposits in the sewers and cesspools. The result of this action was, that nearly 40 per cent. of the children suffered from mild typhoid fever.

The same result happened this spring at the Female Orphan Asylum at Beddington. No provision was made for the ventilation of the sewers in connection with the building, but an accidental opening—accidental at least as far as ventilation was concerned—existed in the plug which acted as an overflow pipe in the latrines. The latrines were in close communication with the class-rooms, into which the children used to go in the early mornings. The class-rooms were not provided with any efficient and certain means of ventilation like the Russell Hill Schools; they are warmed by hot water pipes instead of open fireplaces. Foul air once in the room could not easily get out, and in a short time about 30 per cent. of the children suffered from the effects of sewer gas.

Similar results have happened in other schools, both public and private, within my own observation, but I need not multiply instances. I may, however, give one more illustration, that afforded by the book kept by our Local Board for the registration of stoppages in sewers. Our engineer, Mr. Latham, says, that before the introduction of the plan now adopted by our Local Board, stoppage in the sewer was always coincident, in point of time, with illness in the houses affected by the stoppage. I have at times been able to draw attention to a defective sewer simply from observing on that line of sewer rather more than the ordinary amount of illness of a slight kind, and it has always been found that that sewer had a defective ventilation, and by

remedying that defect the illness on that line of sewer decreased.

The frequent occurrence of these cases led me to consult all the publications upon the subject that I could find, being convinced that a remedy existed. I found especial assistance from the reports of Dr. Letheby and Mr. Heyward, which were published by the City Commission of Sewers in 1858. But while they acknowledged the sufficiency of cause, they did not point out an effective or practical remedy; meanwhile openings were multiplied, as strongly recommended by Mr. Rawlinson, and eventually the Croydon Local Board determined three years ago to adopt the principle of opening the extremity of every sewer, and of every branch or house drain in connection with the sewer, and make every house ventilate the house drain, whilst the Local Board had openings made into the sewers at 100 yards interval, so as to allow of a constant and continuous current of air. By this means the effects of sewer gas have been entirely obviated, and the consequences removed in those portions of our district to which the law is made to apply in a most marked and decisive manner.

The early sanitarians reasoned in favour of small sewers, partly on the idea that they would keep perfectly clean, and that no decomposition could take place, and therefore that no gas products would be formed. Theory and practice do not, however, go together; sewers are never constructed in ordinary towns as the early sanitarians intended that they should be; they do not, as a rule, flush clean; they are often badly laid, and a consequence deposits takes place in them, and decomposition, with the liberation of sewer gas, results. Now this sewer gas makes its way more easily out of the large sewers of London, with the many open gratings existing therein, so as to some extent to obviate the chance of pressure upon the traps which exists much more forcibly in the pipe sewers of less extensive drainage areas. It will form at

times very abundantly in the house drains, and these being, like gas receivers, open at the bottom only, the sewer products will make their way through the traps into the houses ; and if the traps become, as is often the case, untrapped, especially in dry weather, there is a ready means for the entrance of the gas into the house, independently of the means afforded by the water in the trap itself, which is a ready conductor of the miasms—absorbing the agent on one side and giving it off on the other.

Theoretically, ventilation of sewers ought not to be necessary, for, theoretically, no deposit ought to exist in a sewer ; but practically this is found at times an impossibility, and an efficient system of ventilation must be provided.

The experience obtained in extended drainage areas, as well as that from more isolated districts, has shown that trapping is only stopping the danger at one point and forcing it in another direction quite as dangerous to those exposed to its influences. It follows, therefore, that the only satisfactory solution of the difficulty is the prevention of its intrusion into houses at all, and the prevention of its collection in sewers in that concentrated form which leads to mischief. Its formation cannot be prevented, not at least until sewers are so constructed—as to their fall and their workmanship—that no deposit is likely to take place in them at all, and that no settlement shall change their level, whilst the character and the quantity of sewage continues the same. It is seen, therefore, that miasms will form ; how, then, are their influences to be avoided ?

The nature of this miasm has been well pointed out by various chemists and medical authorities ; all concur in the belief that dilution destroys it, that if sufficiently diluted with air it becomes innocuous and its sting is taken away ; when it first escapes from a sewer it carries with it some condition which is injurious to life, tending to prevent some necessary change in the blood, or other vital tissues, either by its own



power, or by means of a property to which it simply bears the relation of carrier. If it be mixed with sufficient air, especially if that air be ozonised, the miasm becomes oxodised and comparatively harmless, or if not so oxodised its presence is not injurious to life. Just as a minute quantity of urea in the blood is not injurious, yet if the purifying influence of the circulation through the kidney be interfered with or obstructed, a rapid change for the worse results. So again with carbonic acid; if the ventilation of lung structure is interfered with serious damage is suffered; even the ordinary ventilation through the pores of the skin must not be stopped, or some change takes place in the body which is not consistent with perfect health.

It is seen that the circulation of air, or of air-carrying fluids is incessant in both plants and animals; that this incessant action is the result in a great measure of chemical and physical changes in the moving fluids; that the safety of animal as well as of vegetable life depends upon the incessant movement. That if this movement can be produced and continued in sewers, no sewer gas could exist in a form sufficiently concentrated to be hurtful to human life.

Professor Graham and others have pointed out that nature has given to gases a law by which they have a tendency to diffuse themselves inversely as the square roots of their densities. This law certainly comes into play as soon as ever the gases are disengaged, at once tending to produce motion in the air. This motion will be assisted by the continuous changes of temperature following upon the quantity of hot water going into the sewer, it will also be encouraged by the presence of a flowing stream, varying in depth, and keeping up a varying circulation, causing an incessant motion of the air; as sewage rushes down air must rush up to occupy the vacant place. Our problem, therefore, is how to render this circulation positively continuous, and to prevent its sinking into that dead calm which arises when the forces oppose one

another, and which then allows the air to become saturated with sewer miasm. This has been effected most perfectly in our district, by compelling every new house to have ventilation for itself. The soil pipe is continued upwards in a straight line above the level of the pan between the trap and the sewer, and it is made to terminate by an open extremity above the eaves of the house away from a window, and not close to or level with a chimney. Every connection with the sewer requiring the presence of a trap has that trap guarded from the consequences of pressure by a ventilator similar to the soil pipe, the latter being placed as close to the trap as possible. It is found necessary to make these shafts ascend straight up, and not curve or turn at right angles, or their efficiency is interfered with. The result of making these innumerable openings at the higher points of the sewer has been to promote a rapid circulation through the sewer, by which all sewer gas is removed as quickly as formed by dilution and deoxidization, and no concentration can take place. If any of the traps which may be considered absolutely necessary in the house should get out of order, then the introduced gas would be comparatively harmless because so diluted; but every communication with the sewer other than that of the w.c. is indirect only.

These innumerable openings act like the pores on the skin, or like the stomates upon the leaves of plants; they are themselves causes of motion, for the air in the sewer of a large town will always have a temperature and density different from that outside; it will always be warmer in cold weather, whilst in hot weather it will be much more loaded with moisture. Differences of temperature, density, and moisture, will always be sufficient to determine a circulation, provided entrances exist for fresh air, as well as exits for that which has passed through the sewer.

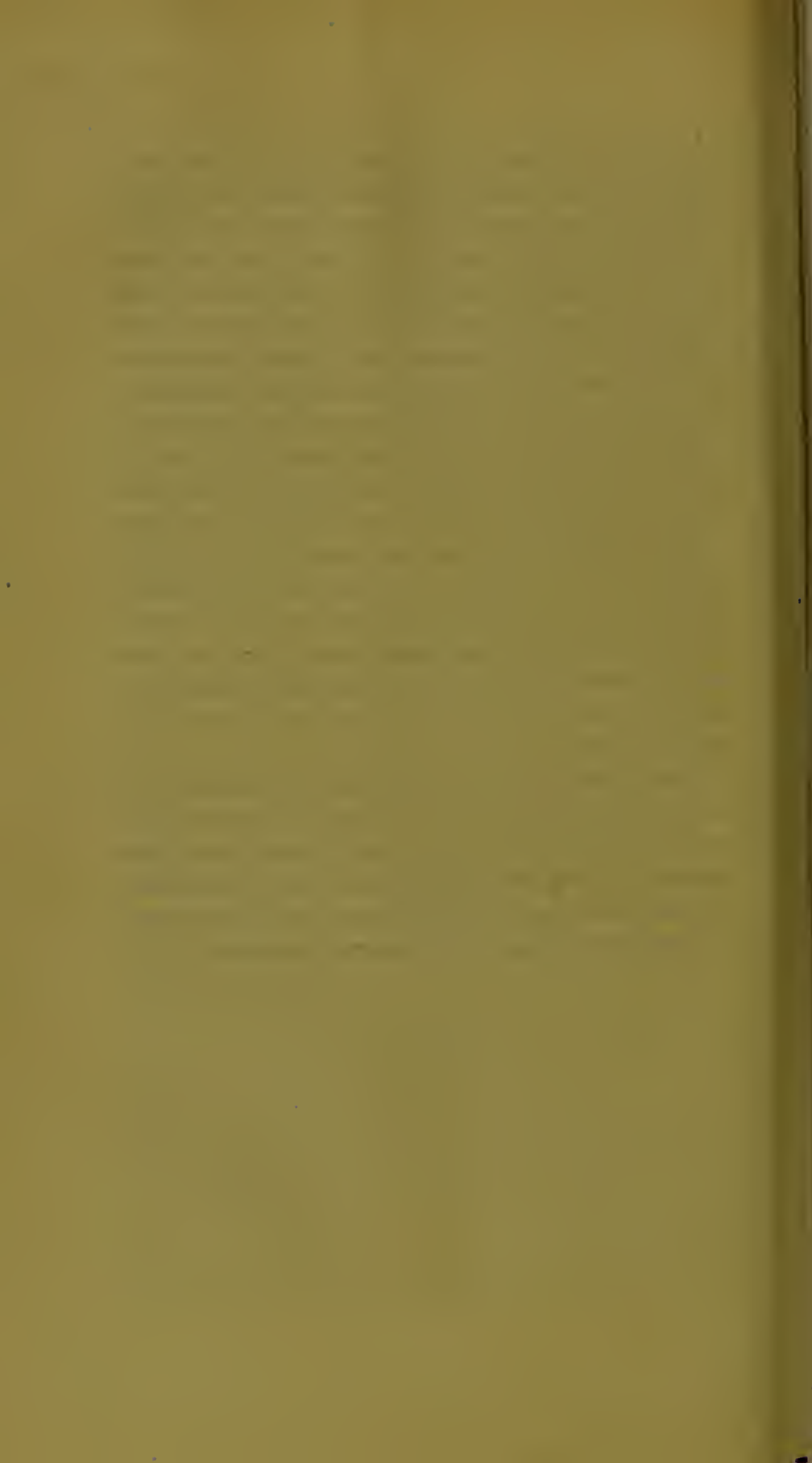
The ordinary manholes and gullies in the streets will provide these openings, and more often lead to a down draft

than to any upward current of foul air. I have often found this to be the case in the ventilating places which have been opened near the lower ends of our Croydon sewers; air enters instead of finding an exit. The principle to be obviated is stagnation, whether of solid, of liquid, or gas—deposit must not be allowed, fluid must always run off; let there be also innumerable openings near the tops of the houses and it may be safely assumed that no stagnation will exist in the sewers themselves, for these openings will be the promoters of incessant movement. Let every water-closet have its movement promoter, its safety valve, in the pipe I have mentioned; let every trap, which it is absolutely necessary to use for the protection of the inmates of a house, be in a similar manner protected; let every pipe, not actually conveying sewage, have an indirect communication with the sewer only. Let all openings in the streets be untrapped, and everything done which will promote sewer circulation, and disease in every way will become, as it has been in Croydon, more tractable, and the effects of drain poison almost unknown.

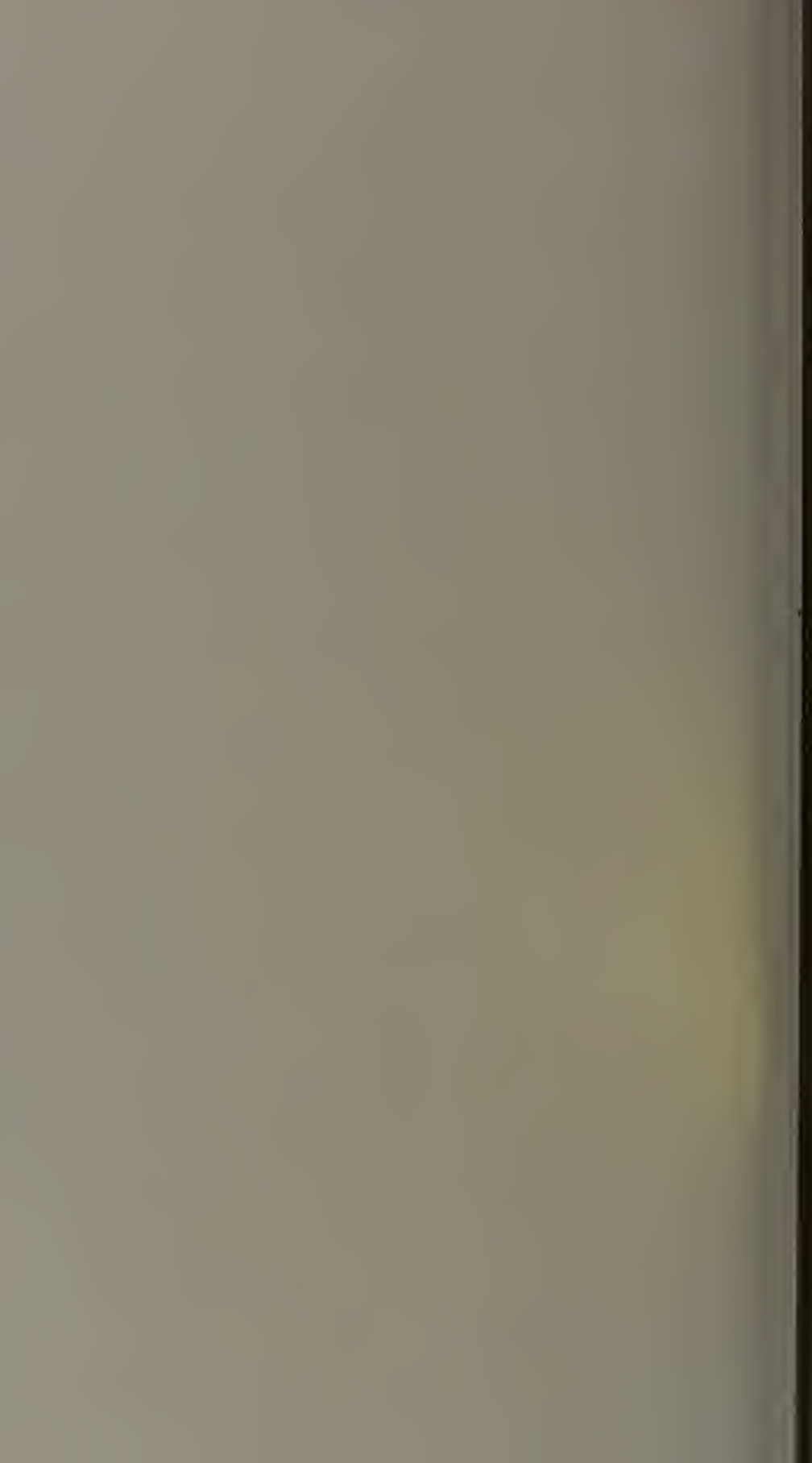
It may be argued that these recommendations apply only to pipe sewers, and will not do for the large culverts now being constructed in London. This I deny; they can be ventilated as well as the Southwark subway or the metropolitan railway tunnels. If they contain deposit they are badly constructed, and such bad work ought to be remedied. It is becoming more and more certain, however, that more mischief arises in the house drains, where stagnation can take place, than in the main sewers in which the main current is ever flowing; it never stagnates sufficiently long to allow of decomposition taking place, except under the most exceptional circumstances, which would be fully guarded against by the precaution of having proper charcoal ventilators in the manholes of the streets, at those places at which an up-current might be established—as at the top of a sewer having a rapid fall towards one on dead level. These ventilators have been

often used in our streets ; a most efficient one has been lately perfected by our engineer, Mr. Latham, by means of which the charcoal is protected from rain, and the air compelled to pass through a double sieve in the way shown the other evening by himself at the Society of Arts. Various other ways may be adopted for the purpose of promoting rapid circulation in the large sewers, better known to engineers than to myself ; but the correct theory of sewer ventilation is undoubtedly motion. Motion is success ; stagnation is destruction or defeat. I have not supported by figures the proposition I have submitted, because it has been found impossible to isolate the districts, so as to place them under the same conditions, but I may simply state that the mortality for the parish of Croydon for the quarter ending March 30, 1869—the quarter which generally has the highest rate of mortality—was 18·53, the deaths from fever in the same quarter were *nil* among nearly 60,000 people. The mortality for London in the same quarter was 25·0 ; that for all England 24·84.

In conclusion, I beg to thank you, Mr. Chairman and gentlemen, for your kind attention, and to beg your indulgence for imperfections. The idea of reading the Paper arose from hearing the other evening, at the Society of Arts, a Paper upon house-drains, which seemed only to urge traps as a remedy for smells. I say ventilate ; don't trap.







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